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Pursuing an ecological component for the Effect Factor in LCIA methods

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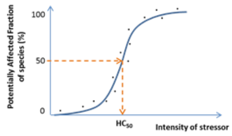
① INTRODUCTION

- Ecosystem-related indicators benchmark impacts as **Potentially Affected Fraction of species** (**PAF**) -> *the fraction of species in a generic community expected to be potentially affected above its no-effect level or other predefined effect level*
- PAF approaches are based on **Species Sensitivity Distribution** (**SSD**) -> *cumulative statistical distribution useful to extrapolate responses/sensitivity of individual species to community's responses/sensitivity*
- LCIA models the **marginal change** in PAF and therefore does not account for the current state of the ecosystem
- PAF can be further modelled to **Potentially Disappeared Fraction of species** (**PDF**) by converting it into damage ($* \ Conv_{PAF \to PDF}$)
- ***Can it also account for the state of the environment***

$Q_{emitted}$ [kg] **x** **CF** [PAF·m³·d/kg] **=** **Impact** [PAF·m³·d] **x** **$Conv_{PAF\text{->}PDF}$** [PDF/PAF] **/ h_w** [m] **= Damage** [PDF·m²·d] (loss of biodiversity)

How can this coefficient be estimated?

② From SSD to Effect Factor

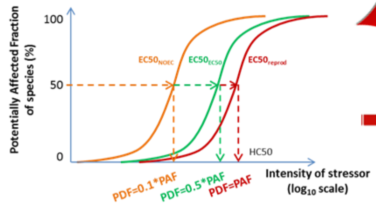


Effect Factor (FF) is calculated with HC50 obtained from SSD methodology:

$$EF = \frac{0.5}{HC_{50}} \quad [PAF \cdot m^3 \cdot d]$$

PAF->PDF conversion factors

ecotox indicators	$Conv_{PAF\text{->}PDF}$	factor	source
HC50 based on chr EC50	PDF = 0.5*PAF	2	IMPACT 2002+ (Jolliet et al. 2003)
HC50 based on NOEC	PDF = 0.1*PAF	10	Eco-indicator 99 (Goedkoop and Spriensma 2000)
effect on reproduction, long term	PDF = PAF	1	Snell and Serra (2000)
HC50 based on LOEL	PDF = ? * PAF	?	discussed here for marine eutrophication



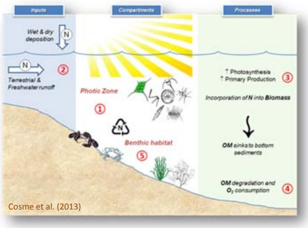
What do they mean? Such factors are equal to change the HC_{50} by 1 or 0.3 log units

Ecosystems state is not included. How much have 'past impacts' affected the ecosystem?

One half, one tenth, or all the species, will not recover from the (toxic) stress and disappear, when adopting the 'recovery time approach', which assumes [1]:

- Biodiversity linked with water quality (species disappear when stress reaches a certain level, reappear after pressure drops below that level)
- Equal time for disappearance and recolonisation and equivalent diversity before and after recolonisation

③ INDICATOR FOR MARINE EUTROPHICATION



The processes

- Excessive increase of primary production in response to inputs of nutrients and organic matter accumulation [2]
- Results in excessive oxygen depletion and impacts on biota, ecosystem and (socio)economy

The modelling

CF estimation in Marine Eutrophication [3]:

$$CF[PAF \cdot m^3 \cdot yr \cdot kgN^{-1}] = FF[yr] \times XF[kgO_2/kgN] \times EF[PAF \cdot m^3 \cdot kgO_2{}^{-1}]$$

Indicator -> Midpoint impact score (IS_{mp}):

$$IS_{mp}[PAF \cdot m^3 \cdot yr] = Q[kgN] * CF[PAF \cdot m^3 \cdot yr \cdot kgN^{-1}]$$

Indicator -> Damage Score (DS):

$$DS\ [PDF \cdot m^2 \cdot yr \cdot kgN^{-1}] = Conv_{PAF \to PDF}[PDF \cdot PAF^{-1}] * IS_{mp}[PAF \cdot m^3 \cdot yr]/h_b[m]$$

(h_b = height of the bottom layer in the marine compartment where hypoxia develops)

In practice, the conversion factor ($Conv_{PAF \to PDF}$) delivers the fraction of affected species that do not recover after the pressure is reduced.

④ NEW CONVERSION APPROACHES

- PAF is built on biological/physiological endpoints – present conversion factors do not add any extra layer of information.
- Duration and intensity are reflected in the EF, but not the 'erosion' of species' tolerance from 'past impacts'.

3 possible approaches to include an **ecological component**:

- **Trait-based approach**: Apply percentage of change (1980-2006) of ecological (trophic level, TL) or biological (maximum length) traits to an initial 0.5 conversion factor. The pressure from 'past impacts' that might have degraded the recovery capacity is reflected in the conversion factor.

LME #	LME name	trait	1980	2006	var	$Conv_{PAF\text{->}PDF}$	factor
3	California Current	mean TL	3.13	3.38	0.08	**0.46**	2.2
		mean max lenght (cm)	45.8	57.8	0.26	**0.37**	2.7
5	Gulf of Mexico	mean TL	2.41	2.50	0.04	**0.48**	2.1
		mean max lenght (cm)	31.0	33.7	0.09	**0.46**	2.2
12	Caribbean Sea	mean TL	3.29	3.14	-0.05	**0.52**	1.9
		mean max lenght (cm)	70.5	48.8	-0.31	**0.65**	1.5
22	North Sea	mean TL	3.37	3.34	-0.01	**0.50**	2.0
		mean max lenght (cm)	50.0	45.4	-0.09	**0.55**	1.8
23	Baltic Sea	mean TL	3.70	3.21	-0.13	**0.57**	1.8
		mean max lenght (cm)	96.1	41.2	-0.57	**0.79**	1.3
40	NE Australian Reef	mean TL	4.01	3.85	-0.04	**0.52**	1.9
		mean max lenght (cm)	156.2	129.0	-0.17	**0.59**	1.7
48	Yellow Sea	mean TL	3.51	3.44	-0.02	**0.51**	2.0
		mean max lenght (cm)	89.2	78.2	-0.12	**0.56**	1.8

Example limited to demersal, benthic and benthopelagic fish species resident in the Large Marine Ecosystems (LME) considered. Other taxonomic groups and traits can be included. Data from seaaroundus.org and fishbase.org .

- **V*R approach**: Integrates **V**ulnerability [4] and **R**esilience [5]. **V** (0-1) proxies for degradation of the community and propensity to be permanently affected. **R** uses population's recovery time, or doubling time (yr) - capacity to withstand fishing exploitation, proxy for propensity to shift to an undesired regime.

Climate zone	spp (n)	GM Vulnerability	GM Resilience	V*R	$Conv_{PAF\text{->}PDF}$	factor
Polar	3	0.66	2.92	1.92	**0.52**	1.9
Subpolar	11	0.48	4.40	2.09	**0.48**	2.1
Temperate	12	0.46	4.40	2.03	**0.49**	2.0
Subtropical	10	0.46	4.82	2.23	**0.45**	2.2
Tropical	3	0.53	11.38	6.01	**0.17**	6.0
Global	12	0.46	4.40	2.03	**0.49**	2.0

Example with data from 5 climate zones and a global default, limited to the 12 demersal, benthic and benthopelagic fish species used in the CF modelling for marine eutrophication [3] – can be expanded to all relevant fish species in LMEs or climate zones. Geometric means (GM) are used. Data from fishbase.org.

- **V*U*R approach**: Integrates **V**ulnerability and species **U**niqueness, weighted by ecosystem's **R**esilience. **V** and **R** are proxies for ecosystem quality. **U** gives higher value to rare species, using the phylogenetic diversity index (PDI) from 0.5 (low) to 2.0 (high, rare) [6].

LME #	LME name	spp (n)	GM Vuln	GM Uniq	GM Resil	sum(V*U*R)	sum(R)	$Conv_{PAF\text{->}PDF}$	factor
1	East Bering Sea	38	0.52	0.65	5.15	90.65	234.40	**0.39**	2.6
9	Newfoundland-Labrador	38	0.56	0.60	5.56	114.07	264.21	**0.43**	2.3
13	Humboldt Current	18	0.47	0.70	4.19	37.75	93.62	**0.40**	2.5
20	Barents Sea	41	0.57	0.66	5.53	121.44	271.90	**0.45**	2.2
23	Baltic Sea	36	0.51	0.64	4.44	80.36	195.33	**0.41**	2.4
26	Mediterranean Sea	59	0.49	0.59	4.16	108.46	301.97	**0.36**	2.8
27	Canary Current	59	0.45	0.59	3.60	88.29	257.39	**0.34**	2.9
31	Somali Coastal Current	7	0.42	0.69	3.82	11.88	36.18	**0.33**	3.0
40	NE Australian Shelf	11	0.44	0.60	3.33	12.02	43.11	**0.28**	3.6
48	Yellow Sea	33	0.47	0.57	3.76	46.42	145.33	**0.32**	3.1

Limited to demersal, benthic and benthopelagic fish species in the LMEs considered. Expansion is difficult due to lack of information and threat level for other taxonomic groups. Geometric means (GM) are used. Data from seaaroundus.org and fishbase.org.

⑤ CONCLUSION

3 approaches for an ecological component to damage estimation were presented. Important for environmental relevance and spatial differentiation of the models.

After this exploratory research, new questions arise regarding:

- The impact of invasive species?
- The weight of keystone species?
- Do different species move in after the disappearance of the 'endemic' ones? How does that affect diversity?
- Should the ecosystem's adaptive capacity be included too?
- Should functional diversity (based on biological/ecological traits) be included to improve the conversion factor?

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